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Rhode Island/Southeastern Massachusetts Jewelry Electroplating and Metal Finishing Industries Environmental Assistance Project

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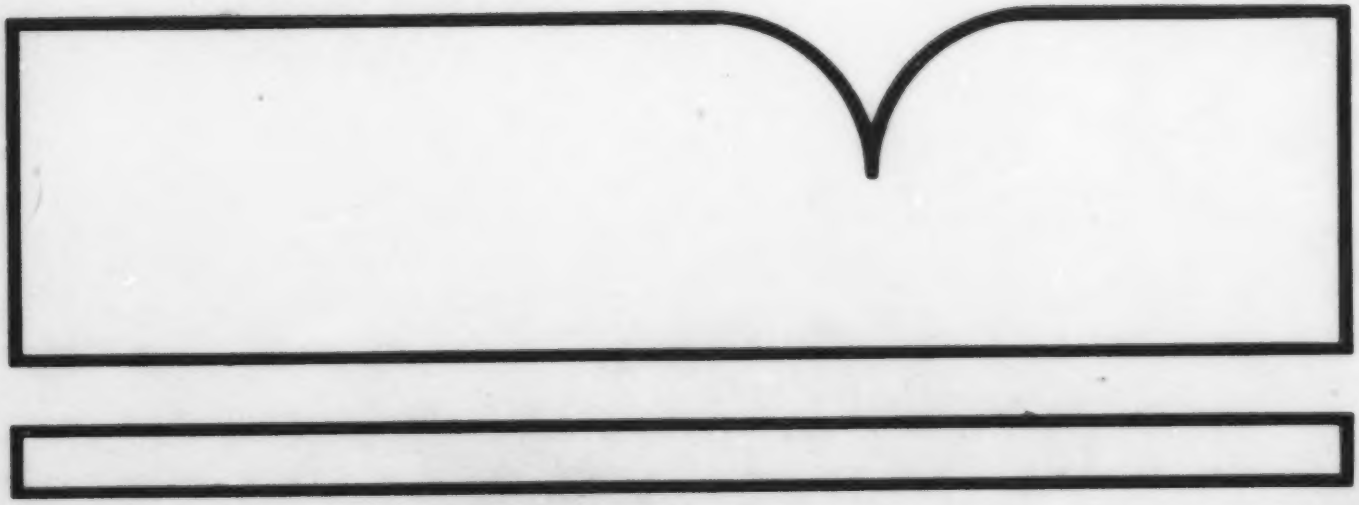

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This report is a summary of the findings of an 18 month study funded by the U.S. Department of Commerce Economic Development Administration, the Manufacturing Jewelers and Silversmiths of America, Inc., and the Rhode Island Department of Economic Development.

The purpose of this study is to assist the metal finishers, predominantly jewelry metal finishers, in complying with U.S. Environmental Protection Agency wastewater pretreatment regulations requiring pollution control of sewer discharges by October 1982.

Due to the high cost of pollution control, USEPA's forecast that 20% of the electroplating job shops would go out of business due to the controls.

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Jewelry, Electroplating and Metal Finishing Industries

Environmental Assistance Project

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METAL FINISHING INDUSTRY
ENVIRONMENTAL ASSISTANCE PROJECT
SUMMARY REPORT

I. INTRODUCTION

This report is a summary of the findings of an 18 month study funded by the U. S. Department of Commerce (EDA), the Manufacturing Jewelers and Silversmiths of America, Inc., and the Rhode Island Department of Economic Development. The purpose of this study is to assist the metal finishers, predominantly jewelry metal finishers, in complying with U. S. Environmental Protection Agency (USEPA) wastewater pretreatment regulations requiring pollution control of sewer discharges by October 1982.

This study was initiated in response to USEPA's forecast that 20% of the electroplating job shops, predominantly the small shops, would go out of business due to the disproportionately high cost of pollution control. It was clear that fresh new solutions to the problem were needed and, therefore, it was necessary to initially define the extent of the problem. Prior to this effort even the number of affected metal finishing firms was unknown. The number, types, locations, water flow, wastewater characteristics and the regulations applicable to metal finishers in the study area were determined from surveys, site visits, and sampling and analyses of wastewaters. Nearly 150 shops have participated in this data gathering program.

From these data alternative technical solutions have been examined and costed for a "typical" small, medium and large jewelry electroplating shop. These alternatives include conventional waste treatment by metals precipitation and cyanide oxidation; advanced methods of ion exchange, electrodialysis, reverse osmosis, electrolysis and evaporation; and many innovative methods at various stages of development.

Also examined were the two approaches of traditional on-site waste treatment versus on-site storage, haul and treatment at a central facility. Economies of scale and opportunities for recovery and sludge minimization were sought as benefits of a central facility.

This report presents only the highlights of the study findings. Supporting documentation and elaboration is available in the form of detailed consultants reports.

II. APPLICABLE WASTEWATER REGULATIONS

Depending on geographic location of the metal finishing shop there are ten (10) different regulations applicable to electroplating wastewater discharges in the Rhode Island and Southeastern Massachusetts study area. The applicable regulation depends on which of the 17 sewer systems a company discharges to or if it discharges to an on-site disposal system or river.

In all cases the most stringent of the federal and local sewer ordinance requirements apply, that is, the federal pretreatment standards apply nationwide as a minimum, but local ordinances can be and some are more stringent.

The federal wastewater regulations apply to 75% of all metal finishers in the area. The federal general pretreatment standards prohibit the discharge of:

1. Pollutants which would interfere with the publicly owned treatment works (POTW) operations,
2. Pollutants which could cause an explosion or combustible condition,
3. Pollutants with a pH less than 5.0,
4. Solid or viscous pollutants which clog the sewer; and
5. Hot wastewater which would result in a wastewater to the POTW in excess of 104°F.

The pollutant concentrations contained in the federal specific pretreatment standards, in proposed form at the time of this study and requiring compliance by October, 1982, are as follows:

REGULATED POLLUTANTS	STANDARDS (mg/l) For Shop Process Flows Less Than 10,000 gpd		For Shop Process Flows Greater Than 10,000 gpd	
	Daily Max.	4 Day Avg.	Daily Max.	4 Day Avg.
Amenable*Cyanide	5.0	2.7	-	-
Total Cyanide	-	-	1.9	1.0
Lead	0.6	0.4	0.6	0.4
Cadmium	1.2	0.7	1.2	0.7
Total Chromium	-	-	7.0	4.0
Copper	-	-	4.5	2.7
Nickel	-	-	4.1	2.6
Zinc	-	-	4.2	2.6
Silver	-	-	1.2	0.7
Total Metals	-	-	10.5	6.8
Total Suspended Solids	-	-	20.0	13.4

*Amenable means destroyed by alkaline chlorination.

The local sewer ordinance standards are too numerous and varying to describe here. However, this information can be best obtained through your local government. A summary of all regulations is contained in the Appendices Volume I, Typical Jewelry Electroplating Shop Models of this study report.

In addition, newly enacted state and federal hazardous waste regulations will continue to have significant impact on companies disposing of wastewaters on-site by subsurface or surface (lagoon) means. Also, disposal of wastewater treatment plant metal hydroxide sludges has become very costly in recent months due to the federal generic classification as "hazardous" following the closing of all hazardous waste landfills in Rhode Island. The nearest legal landfill site is in upperstate New York and recently reported costs for haul and disposal are $75.00 per drum - up from $40.00 per drum only one year ago. There does not appear to be a regional landfill solution for metal hydroxide sludges in the near future.

III. INDUSTRY AND WASTEWATER CHARACTERISTICS

To define the extent of the problem mail surveys were sent to possible metal finishers in the study area. The surveys were sent to 1455 firms. Of these, 37.7% were returned. 50% of all MJ&SA members responded. This survey defined the total number of known or suspected metal finishers in the area as 420, 297 of which are jewelry firms, and 123 are non-jewelry metal finishers. Jewelry metal finishers were classified by size from reported water flows obtained from about 140 shops without treatment. Little data was provided by non-jewelry metal finishers.

The following industry size grouping of jewelry metal finishers, without in-shop treatment was selected:

Size	No. of Shops	Percent of Total
Small (less than 15,000 GPD) (5850 GPD avg.)	119	(46%)
Medium (15,000-70,000 GPD) (35,850 GPD avg.)	101	(40%)
Large (above 70,000 GPD) (183,800 GPD avg.)	33	(14%)
	253	100%

The geographical distribution of these 253 jewelry metal finishers without treatment is as follows:

Providence Sewer District	145
Warwick	12
East Providence	13
Cranston	12
Blackstone Valley Sewer District	24
Bristol	1
Smithfield	3
Attleboro	24
N. Attleboro	6
New Bedford	1
Fall River	1
Taunton	9
Coventry	1
N. Kingstown	1
	253

This distribution is depicted in Figure 1.

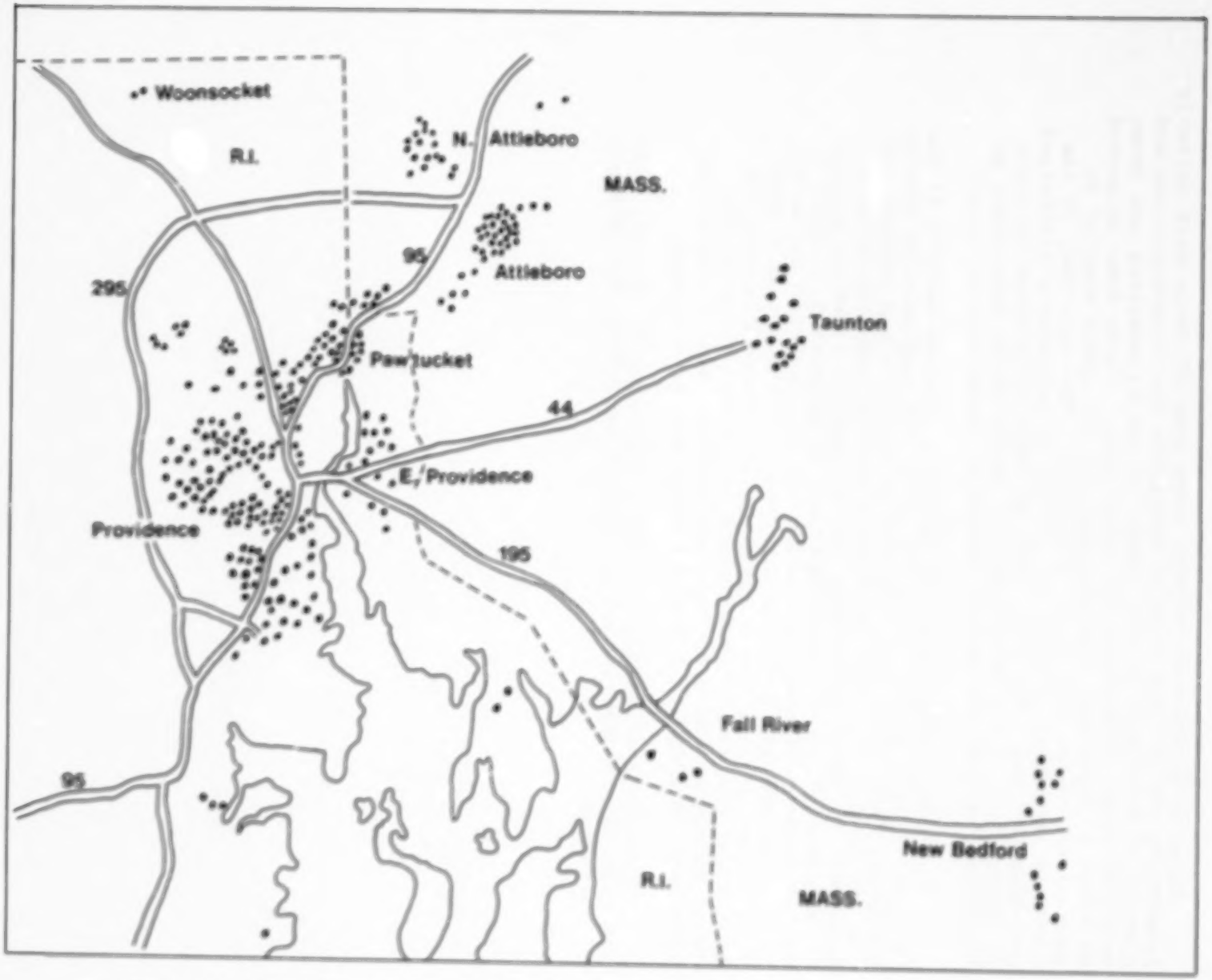


Figure 1 - Geographic Distribution of Known or Suspected Metal Finishers in the Study Area

Along with the mail survey, more than 55 shops were initally sampled by the Project Team to determine the concentrations and quantities of regulated pollutants in the rinsewaters and spent solution dumps throughout the study area. These data presented as Table 1, represent the averages for all shops sampled in each of the three shop size categories. The main body of the table is presented in terms of pounds of pollutants discharged per shop per day. The last line on Table 1 is given in terms of average pollutant concentration (mg/l) which were found to be about the same for small, medium or large jewelry shops.

In order to determine the specific process sources of the pollutants from within a typical shop, two medium size jewelry electroplating shops were sampled in detail - one captive and one job shop. The results of this limited sampling allow a breakdown of major pollutants and rinsewater flows by sources in a "typical" shop. This breakdown is presented in Table 2, as the percent of total pollutant and percent of total wastewater flow emanating from each process source within a shop. Some rinses such as the rinse after ultrasonic cleaning and that after the electrocleaner may be allowed to go to the sewer in compliance with the regulations. Due to variations from shop to shop, this must be confirmed by analysis.

These data from Tables 1 and 2 were used to select, size, and cost alternative pollution control equipment for purposes of comparison.

TABLE 1

"TYPICAL" JEWELRY SHOP EFFLUENT CHARACTERISTICS
LBS/DAY

Shop Size	Water Use (Gal/Day)	Total Cyanide	Chromium	Copper	Nickel	Zinc	Lead	Cadmium	Silver	Gold	Iron	Tin	Total Metals
SMALL													
rinse-water	5,830	0.39	0.01	0.40	0.53	0.14	0.008	0.0021	0.0042	0.007	0.10	0.024	1.25
dumps	20	0.11	-	0.05	-	0.03	-	-	0.0007	-	0.007	0.001	0.21
total	5,850	0.50	0.01	0.45	0.53	0.17	0.008	0.0021	0.005	0.007	0.12	0.025	1.46
MEDIUM													
rinse-water	35,720	2.4	0.061	2.48	3.30	0.86	0.046	0.012	0.024	0.043	0.64	0.15	7.6
dumps	130	0.66	-	0.27	0.03	0.19	0.002	-	0.004	0.001	0.045	0.009	0.56
total	35,850	3.1	0.061	2.75	3.33	1.05	0.048	0.012	0.028	0.044	0.688	0.16	8.2
LARGE													
rinse-water	183,140	12.3	0.31	12.7	16.9	4.41	0.24	0.065	0.130	0.22	3.3	0.75	39
dumps	660	3.4	-	1.41	0.11	0.93	0.01	0.001	0.018	0.004	0.23	0.04	2.76
total	183,800	15.7	0.31	14.1	17.0	5.34	0.25	0.066	0.15	0.22	3.5	0.79	42
Average Industry Concentrations (mg/1)		8.4	0.28	8.5	10.7	3.0	0.20	0.05	0.09	0.14	2.3	0.48	26.

TABLE 2

ORIGIN OF THE POLLUTANTS AND RINSEWATERS FROM A "TYPICAL" JEWELRY ELECTROPLATING SHOP

Process	Percent of Total Pollutant Mass										Percent of Total Rinsewater Volume	pH
	Cyanide	Copper	Nickel	Zinc	Silver (Predicted)	Lead	Cadmium	Iron	Gold	Tin		
Soap Rinse	4%	3%	1%	9%	Low	BD	BD	10%	85%	-	13%	8-10
Acid Cleaner Rinse	-	2%	1%	6%	Low	BD	Present	20%	-	28%	24%	3-4
Cyanide Cleaner Rinse	54%	1%	4%	1%	Low	BD	Present	4%	-	-	10%	8-10
Electrocleaner Rinse	1%	1%	1%	3%	Low	BD	BD	19%	-	20%	12%	8-10
Ultrasonic Rinse	1%	1%	1%	1%	Low	BD	BD	1%	-	-	3%	8-10
Fire Dip Rinse	1%	1%	1%	1%	30%	BD	BD	1%	-	-	1%	9-10
Copper Strike Rinse	40%	74%	1%	1%	Low	BD	BD	-	-	-	11%	7.5-9.5
Nickel Plate Rinse	-	1%	94%	1%	Low	BD	BD	1%	15%	-	18%	4-6
White Plate Rinse	2%	2%	1%	30%	Low	BD	Present	-	-	52%	13%	8-9
Bright Dip Rinse	-	21%	1%	60%	20%	Present	Present	46%	-	-	6%	2-3

NOTES: 1) Dragouts from other processes such as Brass or Bronze plating will be important in certain shops but are not widely used, so are not included here.

2) Most cyanide was analyzed as amenable.

3) Silver was not measured in either detailed shop sampled - location will depend on how much silver plating is done and how much sterling base metal is used.

BD - Below detection

\- Less than

Table 3 presents an estimate of the amount of pollutants currently discharged by the jewelry electroplating industry in the study area.

TABLE 3

DAILY AMOUNT OF POLLUTANTS DISCHARGED BY THE 253 JEWELRY ELECTROPLATERS WITHOUT TREATMENT

POLLUTANT	POUNDS/DAY DISCHARGED AVERAGE	RANGE
Chromium	21	3-39
Cyanide	625	412-837
Nickel	798	569-1028
Copper	663	415-850
Lead	16	11-20
Zinc	227	163-291
Cadmium	2.6	0-5.2
Tin	37	NA
Silver	5.2	1.3-9
Iron	170	NA
Gold	10.4	NA
TOTAL	2545	1574 to>3079

(1) Range includes 90% confidence intervals
NA Not Available

IV. WATER AND WASTE REDUCTION METHODS

Why Reduce Water and Wastes?

Up to now there has been little incentive for the plater to minimize water use and waste generated. Raw water and sewer costs are usually low and regulatory requirements to remove pollutants from wastewater have been non-existent or poorly enforced. However, with the implementation and enforcement of federal environmental regulations, the incentives for reductions in water use and waste generation become significant. Some of these added incentives are:

1. A reduction in capital and operating costs of waste treatment,
2. A reduction in water and sewer use charges,
3. A reduction in process chemicals lost to the sewer by dragout, and
4. A reduction in sludge quantities requiring disposal.

How To Reduce Water Use

Prior to actually starting the work of water and waste reduction, a comprehensive plan should be prepared for your shop. Because of the many methods discussed, some are mutually exclusive, that is, one particular method may not be used in conjunction with another.

Because rinse waters comprise the largest flow volumes in the plating shop, methods for reducing rinse flows should be implemented to some degree in all cases. There are five basic methods for water reduction which range in cost from a few dollars to several hundred dollars. The key to maximum water reduction is to use rinse water in the most efficient manner. The five major methods for reducing water use are as follows:

1. Improved Rinsing Efficiency Via Agitators.
   Rinsing is optimized by vigorously moving the water around the workpiece. The more vigorous the rinse, the less volume of water required. The best agitation is derived using air introduced as an integral part of some flow restrictor device or under pressure through drilled piping located at the bottom of each rinse tank.

2. Flow Controllers.
   The two common types of controllers are the simple water flow restrictor and the more complex conductivity controllers.

The water restrictor limits the flow of water to a predetermined maximum rate and is best used where production rates and work are fairly consistent.

The conductivity controlled system depends on sensing the dissolved solids content of the rinsewater from each tank, using an immersed electrode, and that the conductivity measurement adequately reflects conditions in the tank necessary to maintain product quality. The flow of water to the rinse tank is automatically regulated to maintain a preselected contaminant concentration level within the tank. This system is useful where production rates and work loads vary significantly. Proper maintenance of the probe is necessary for proper performance. Self-cleaning electrodes are also available to minimize such maintenance.

3. Counter-Current Rinse Tanks.

Counter-current rinse tanks allow reuse of water from one tank section to the next. As a result, a counter-current rinse tank can operate at much lower flows than a single rinse tank while maintaining identical final rinse contaminant concentrations. Flow reductions in excess of 90% are possible.

4. Fog-Spray Rinses.

In a spray rinse tank, work removed from the plating bath can be sprayed with a finely atomized, low volume of water. This "fog" dilutes the plating solution film on the work piece and speeds its drainage. A low volume concentrated solution results at the bottom of the rinse tank.

5. Rinse Water Reuse.

It is many times possible, although not always practical, to reuse rinse water output from one rinse tank as input to one or more rinse tanks at other locations in the process line. When used properly, this will save water and may actually improve rinsing.

How To Eliminate, Reduce and Concentrate Wastes

The following discussion provides a logical step-by-step description and sequence for waste elimination, reduction and concentration in your shop.

After determining your regulatory compliance status by wastewater sampling and analysis, you should embark on the following program:

1. First, you must identify and quantify your sources of pollution - not all waste streams are polluting and further sampling and analyses may be required. Don't forget floor spills, leaks and filter cleaning residuals in this inventory.

2. Second, you should try to eliminate the use of polluting chemicals by substitution with non-polluting chemicals wherever possible. Chrome based anti-tarnish or bright dips are good candidates for elimination.

3. Third, you should segregate polluting streams from non-polluting streams. Also, further segregate the polluting streams into at least three categories - cyanide bearing, acid/alkali bearing and chrome bearing streams.

4. Fourth, you should reduce chemical losses due to bath dragout. This includes polluting cleaning baths as well as plating baths. The use of wetting agents and sufficient rack and barrel drain times can reduce dragout volumes as much as 50%.

5. Next, that dragout which cannot be eliminated or reduced should be concentrated by relatively simple means of dragout tanks and/or fog spray tanks. A novel dragout concentration method will be explored in more detail in this report. This method is the most significant finding of this study.

6. Finally, in some cases concentrated dragouts can be returned to the plating and cleaning bath if proper bath control is practiced and bath evaporation rates allow for return of this volume. Nickel, the single metal pollutant of largest quantity is particularly amenable to in-shop reuse. Where concentrated polluting dragouts cannot be returned to the bath, they must either be processed in-shop via batch or continuous treatment or stored and hauled to a central recovery/ treatment facility.

All of the methods are dependent on one factor: the plater. It is important that your platers know the environmental and cost advantages of water and waste reduction. Without their understanding and cooperation, no water and waste minimization program can be successful.

V. CONVENTIONAL TREATMENT METHODS

The industry's wastewater pollutant constituents may be divided into three major categories: cyanides, metals and acidity. The following summary will discuss methods and costs of treating these wastes both in-shop and at a central facility. We have examined all major conventional types of treatment.

Cyanide destruction is frequently performed in a two-stage oxidation treatment system. The first stage of the reaction oxidizes cyanide to cyanate, the second stage oxidizes cyanate to nitrogen and carbon dioxide. The oxidation process most commonly used and also suggested as most applicable for this industry is alkaline chlorination. At a pH of 10 or greater, the first stage oxidation proceeds rapidly (less than 15 minutes). Second stage oxidation requires a lower pH (below 10) and proceeds more slowly, with common detention times of 45 to 90 minutes. Adequate reactor mixing and ventilation are prerequisites for both reaction stages. This process can be employed in either a bath or continuous mode with pH and free chlorine instrumentation routinely used to control the reaction efficiency.

Metals are most commonly removed from mixed wastewaters through the formation of insoluble metal hydroxide solids (precipitates). This step is followed by the separation of these precipitates from the water resulting in a metal hydroxide sludge. The pH of the wastewater is adjusted by the controlled addition of alkalinity in the form of caustic or prepared lime. Caustic neutralization is the most common method for pH neutralization/metals precipitation in small to medium sized wastewater treatment systems due to the ease of handling caustic compared to lime. In larger systems the purchase cost savings of lime in the form of $Ca(OH)_2$ may justify the additional equipment necessary to handle and slurry the lime before use. With either chemical, two stage pH adjustment is usually necessary to attain the narrow pH range necessary for precipitation of mixed metal wastes.

Liquid/solid separation is usually accomplished by gravity settling with the aid of coagulants and/or polymers. The dilute sludge slurry thus formed is gravity thickened further and may be dewatered by a centrifuge or filter press to a solid content of from 10 to 40%. In the case of small and some medium size shops, the large capital expense of equipment may justify shipping the thickened sludge slurry to a central facility for dewatering and disposal.

The final step in this mode of treatment is ultimate disposal of the sludge. Since electroplating sludges have been categorically listed as "hazardous" by the USEPA the sludge must be sent to a licensed secure landfill. This currently means hauling 600 miles to upper New York State where one facility is reported to have a 25 year remaining life.

The volume of water requiring treatment is the primary factor in sizing and costing conventional treatment equipment. Treatment equipment cost reductions can be realized through flow reduction. A proper balance of costs must be sought between the added cost of flow reduction and the savings derived from smaller treatment equipment. Although lower costs could be possible with more drastic and costly means of reductions in flow, we believe a 50% reduction in flow is practical. Even this reduction allows greater than $40,000 savings in total annual operating costs (including amortized capital cost) for the "typical" large shop having a flow of 183,800 gallons per 8 hour day.

Approximate space requirements for waste treatment equipment are:

Small shop (5,850 GPD) = 350 to 400 square feet
Medium shop (35,850 GPD) = 450 to 500 square feet
Large shop (183,899 GPD) = 1000 square feet.

The least cost schemes using conventional treatment are detailed in Tables 4 and 5 for capital and total annual costs, respectively. The costs predicted if the federal 10,000 GPD exemption was removed are also given on these tables.

Table 4
CAPITAL COST BREAKDOWN OF
LEAST-COST CONVENTIONAL PROCESSING SCHEMES AT 50% FLOW
WITH AND WITHOUT THE 10,000 GPD EXEMPTION

Shop Size	Small (5850 GPD)	Medium (35,850 GPD)	Large (183,800 GPD)
Scheme	Batch Cyanide chlorination and continuous pH adjustment	In-shop continuous cyanide chlorination, pH adjustment/metals precipitation, and settling. Haul sludge slurry to central @ 30¢/gal.	Same as Medium but dewater sludge in-shop and send to a landfill @ $135/ton, bulk
Tanks	$ 3,800	$ 5,200	$ 17,800
Pumps	8,400	15,000	29,000
Instruments	5,000	20,000	20,000
Agitators	3,000	6,300	10,800
Settling Unit	0	32,000	32,000
Installation	4,000	15,100	21,900
Piping	4,800	18,100	26,300
HVAC	3,000	5,000	7,000
Electrical	2,400	7,600	11,000
Miscellaneous	6,000	18,200	26,400
Dewatering Equip.	0	0	64,400
Sub Total	40,400	142,500	266,600
Contingency	8,080	28,500	53,300
Engineering	6,070	21,380	40,000
Flow Reduction	9,200	31,000	61,700
TOTAL	$63,750	$223,380[2]	$421,600
With exemption removed	$87,500[1]	$223,380[2]	$421,600

1) Increased cost due to the need for on-site metals precipitation, settling and hauling the dilute sludge to a central dewatering and disposal facility at 30¢/gallon.
2) However, this cost is very close to on-site sludge dewatering which is $266,380 and any given medium size shop could go either way.

Table 5
ANNUAL COST BREAKDOWN OF
LEAST-COST CONVENTIONAL PROCESSING SCHEMES AT 50% FLOW
WITH AND WITHOUT THE 10,000 GPD EXEMPTION

Shop Size Scheme	Small (5850 GPD) Batch cyanide chlorination and continuous pH adjustment	Medium (35,850 GPD) In-shop continuous cyanide chlorination, pH adjustment/metals precipitation, and settling. Haul sludge slurry to central @ 30¢/gal.	Large (183,800 GPD) Same as Medium but dewater sludge in-shop and send to a landfill @ $135/ton bulk
Treatment Chemicals:			
NaOH and NaOCl	$ 1,600	$ 8,775	$ 37,557
Polymer	56	470	2,500
Misc. (Acids,etc.)	250	1,560	6,000
Sludge Disposal	--	7,912	3,200
Water Usage	260	1,575	8,050
Sewer Charge	660	4,050	20,700
Analytical Costs	2,400	4,800	4,800
Labor	7,500	15,000	15,000
Maintenance	1,000	1,500	2,600
Service Contracts	1,500	3,000	3,000
Power	450	1,000	2,400
Amortization	11,284	39,538	74,623
TOTAL	$26,960	$89,180(2)	$180,430
With exemption removed	$33,510(1)	$89,180(2)	$180,430

(1) Increased cost due to need for on-site metals precipitation, settling and hauling the dilute sludge to a central dewatering and disposal facility at 30¢/gallon.
(2) However, this cost is very close to on-site sludge dewatering which is $89,570/year and any given medium size shop could go either way.

VI. ADVANCED TREATMENT AND RECOVERY

A frequently asked question which has never been adequately addressed for the jewelry electroplating industry is whether the five major advanced treatment technologies; reverse osmosis, ion exchange, electrodialysis, electrolysis and evaporation, can be utilized in the electroplating shop to minimize the costs of wastewater treatment and reduce or eliminate the generation of sludges. In effect all advanced methods except electrolysis are waste concentrating techniques only. Electrolysis can also detoxify, however, post treatment to attain standards is usually necessary.

This discussion will describe the various advanced methods, determine their optimum and most economical application, and present a least-cost advanced treatment scheme for a "typical" small, medium, and large sized jewelry electroplating shop. Due to waste variations from shop to shop it is always important to test advanced methods to prove their applicability prior to equipment purchase.

Description Of Advanced Treatment Methods

The following is a brief description of each of the five advanced methods and their applicability to the jewelry electroplater.

1. Reverse Osmosis

   In reverse osmosis, pressure is applied (400-800 psig) to the more concentrated solution (rinse stream) side of a semi-permeable membrane causing the permeate (clear water) to diffuse through the membrane in the direction opposite to the osmotic pressure. The concentrated solution of dissolved solids left behind can be further treated or reused while the clear water can be used again as rinse water. Reverse osmosis has been demonstrated on the following specific electroplating baths: watts nickel, copper sulfate, copper pyrophosphate, acid zinc, chromic acid, copper cyanide, cadmium cyanide and zinc cyanide. The method may also be used to concentrate mixed plating wastes if the pH is not too high and if specific mixed waste testing is conducted to verify treatability.

2. Ion Exchange

Ion exchange is a process where a chemical solution (wastewater) is passed through an ion exchange resin and polluting ions from the chemical solution are exchanged for an equivalent number of non-polluting ions which are stored on the ion exchange resin. When the exchange resin is exhausted, the resin can be restored to a usable condition by regeneration. The backwashed contaminant concentrate (eluate) must still be treated or recovered. This method has been demonstrated for capture of chemicals from the following electroplating rinsewaters: nickel sulfate, gold, silver, and mixed metal-cyanide wastes in end-of-pipe-treatment. It is reported that water reuse is possible for some rinsewaters.

3. Electrodialysis

Electrodialysis employs semi-permeable membranes having anion and cation exchange properties which are alternately stacked in a press with narrow passageways between membranes. When direct current is applied to electrodes on either side of the stacked membranes, the anions and cations of the processed solution migrate toward the anode and cathode, respectively. Because the cation exchange membranes allow only the passage of cation, and the anion exchange membranes the passage of anion, the alternating of membranes create concentration and dilution in the alternate compartments or cells of the stack. This method has been demonstrated for concentration of the following electroplating rinses: acid nickel, acid copper, cyanide copper, cyanide zinc, brass, bronze, and cadmium cyanide. Some problems have been experienced. However, they do not appear insurmountable.

4. Evaporation

Evaporation is accomplished by heating and vaporizing rinsewaters after flow reduction, thus increasing the chemical (pollutant) concentration of the solution. The concentrate can be reused or treated. The water vapor may be exhausted or condensed and recycled back to the rinse tanks. Evaporators have been demonstrated on the following electroplating baths: chromium, acid nickel, acid and cyanide copper, acid and cyanide zinc, silver, brass, bronze, and cadmium cyanide.

5. Electrolysis

Various types of electrolytic reaction have been demonstrated but only one, having sufficiently high removal efficiencies, is approaching commercial operation on non-precious metal waste solutions. This unit, which is designed to remove cyanides, metal cyanides, and heavy metals, uses carbon fibers between the electrodes to increase the mass transfer rates of metal and cyanides from solutions and to maintain a controlled and uniform electrode potential over the entire electrode surface. The system is claimed to electro-oxidize and destroy cyanides more efficiently than the alkaline chlorination process. Metals may be recovered with this technique. Because of the relative newness and untested nature of this method, no recommendation can be made for its use in an electroplating operation without pilot testing.

In general, reverse osmosis and ion exchange are best used to concentrate dilute wastewaters; and electrodialysis, evaporation and electrolysis apply best to further concentrate already concentrated wastewaters. In most all shops conventional waste treatment is still required in addition to the advanced methods.

In-Shop Application

The five advanced methods were screened for application to the "typical" medium size jewelry shop. From this screening a combination of ion exchange and reverse osmosis was selected as being technically feasible and having the least total annual cost. The application of reverse osmosis to combined cyanide streams appears feasible under the proper conditions. However, to our knowledge this has not been demonstrated and a thorough investigation is necessary prior to any equipment selection. Costs of advanced processing would increase if this method is found unfeasible in some shops. Ion exchange applied to bright dip and nickel rinsewaters has been demonstrated.

A scheme was developed and costed for a small, medium and large shop for three cases - (1) with and without the federal 10,000 gpd exemption, (2) with and without materials recovery after concentration, and (3) with and without a central processing facility.

The least-cost advanced processing schemes are presented as Table 6. and 7.

TABLE 6
LEAST COST ADVANCED PROCESSING SCHEMES
WITH AND WITHOUT THE 10,000 GPD EXEMPTION
CAPITAL COST

	SMALL SHOP 5,850 gpd	MEDIUM SHOP 35,850 gpd	LARGE SHOP 183,800 gpd
Advanced Methods	$ 29,260	$ 55,670	$619,837
Dragout Set up	-	11,000	11,000
Batch Treatment	11,293	12,560	18,382
pH Neutralization	15,000	15,000	15,000
Total Capital Cost	$55,553[1]	$ 94,230[3]	$664,219[5]
If 10,000 gpd exemption is dropped	$70,268[2]	$123,370[4]	$564,509[6]

Schemes

1. Nickel and bright dip rinses to pH adjustment, cyanide plating rinses to reverse osmosis, cyanide dumps and concentrates to conventional batch treatment.

2. Nickel and bright dip rinses, reverse osmosis concentrate from cyanide bath rinses, and batch dumps to conventional batch treatment. pH adjustment.

3. Nickel and bright dip rinses to pH adjustment, cyanide plating rinses to reverse osmosis, dragout tanks on non-polluting streams, concentrates and cyanide dragouts to conventional batch treatment.

4. Nickel and bright dip rinses, reverse osmosis concentrate from cyanide bath rinses, and batch dumps to conventional continuous treatment.

5. All plating rinses to reverse osmosis, concentrate recovery of nickel, copper cyanide, and brass, dragout tanks on non-polluting streams, non recoverable concentrates to conventional batch treatment, pH adjustment.

6. Nickel and bright dip rinses to ion exchange, cyanide plating rinses to reverse osmosis, concentrate recovery of nickel, copper cyanide and brass, non-recoverable concentrates and dump solutions to conventional batch treatment, pH adjustment.

TABLE 7
LEAST COST ADVANCED PROCESSING SCHEMES
WITH AND WITHOUT THE 10,000 GPD EXEMPTION
OPERATING COST

	SMALL SHOP 5,850 gpd	MEDIUM SHOP 35,850 gpd	LARGE SHOP 183,800 gpd
Amortization	$ 9,833	$ 16,679	$117,567
Labor	6,750	16,500	48,750
Plant Overhead	430	1,000	4,750
Equipment Replacement	2,500	3,500	17,500
Utilities	535	805	2,695
Analytical Costs	2,400	4,800	4,800
Chemicals	1,516	4,159	8,228
Water & Sewer Charges	1,101	1,130	2,465
Chemical Savings	-	-	(22,802)
TOTAL Annual Cost	$25,065[1]	$ 48,573[3]	$183,953[5]
If 10,000 gpd exemption is dropped	$31,978[2]	$ 62,335[4]	$208,298[6]

Schemes

1. Nickel and bright dip rinses to pH adjustment, cyanide plating rinses to reverse osmosis, cyanide dumps and concentrates to conventional batch treatment.

2. Nickel and bright dip rinses, reverse osmosis concentrate from cyanide bath rinses, and batch dumps to conventional batch treatment. pH adjustment.

3. Nickel and bright dip rinses to pH adjustment,cyanide plating rinses to reverse osmosis, dragout tanks on non-polluting streams, concentrates and cyanide dragouts to conventional batch treatment.

4. Nickel and bright dip rinses, reverse osmosis concentrate from cyanide bath rinses, and batch dumps to conventional continuous treatment.

5. All plating rinses to reverse osmosis, concentrate recovery of nickel, copper cyanide, and brass, dragout tanks on non-polluting streams, non-recoverable concentrates to conventional batch treatment, pH adjustment.

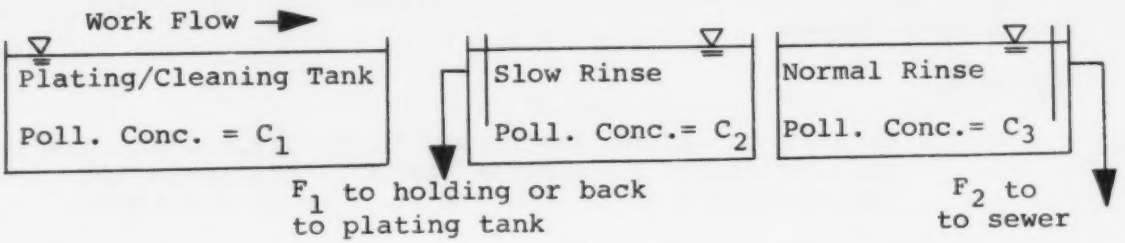
6. Nickel and bright dip rinses to ion exchange, cyanide plating rinses to reverse osmosis, concentrate recovery of nickel,copper cyanide and brass, non-recoverable concentrates and dump solutions to conventional batch treatment, pH adjustment.

VII. INNOVATIVE TREATMENT AND RECOVERY

Probably the most important finding of this study is a very simple innovative method of waste containment recently referred to as the "Providence method". This method can be used to contain wastes and greatly reduce volumes of waste requiring either (1) haul to central, (2) in-shop treatment or (3) reuse in-shop.

The basis of this technique is that most of the contaminating dragout, whether from a plating or cleaning tank, is trapped in one or more "dead" or "trickling" dragout tanks and never enters the flowing rinse which goes to the sewer. With most of the dragout trapped, a final clean rinse of running tap water is allowed to go to the sewer in compliance with standards.

The single trickling tank scheme is illustrated below:



When concentrations are in mg/l and water flows and dragout (D.O.) are in ml/hr:

$$C_2 = \frac{C_1 \ (D.O.)}{(D.O. + F_1)}$$

and

$$C_3 = \frac{C_1 \ (D.O.)^2}{(D.O. + F_1) \ (D.O. + F_2)}$$

One can set F_2 to an average or fairly low flow rate for a rinse tank as seen currently in the industry, determine the dragout rate as measured in our study and calculate the flow, F_1, necessary for a given plating or cleaning tank at concentration, C_1, to go to the sewer in compliance at concentration, C_3. If F_1 is below the calculated evaporation rate on a hot plating or cleaning tank, the trickling rinse could, with purification, be poured directly back to the bath in many cases. If not, this solution could be batch treated in the shop or stored for haul to a central

processing plant.

Instituting a counterflow double dragout tank rather than a single dragout tank can drastically further reduce the amount of concentrate for reuse or treatment.

The relationship is:

$$F_{1,2} = F_{1,1} \ (D.O.)^2$$

where $F_{1,2}$ is F_1 using a counterflow double dragout and $F_{1,1}$ is F_1 with a single dragout tank. We recommend the engineer assume only one dragout tank for design purposes, but install two tanks. A safety factor of 4 to 5 is achieved to accommodate days of extra heavy production.

An estimate of the total volumes of simple dragout and spent solutions which would be generated from a "typical" small, medium and large shop and the total jewelry industry in the study area is summarized below:

Shop Size	Dragout Concentrate Volume Per Shop (Gals. Per Day)	Solution Volume Per Spent Shop (Gals. Per Day)	Total Concentrate Volume Per Shop (Gals. Per Day)
Small	66	23	89
Medium	454	128	582
Large	1550	665	2215

	Number of Shops Requiring Treatment	Daily Total Volume (Gals. Per Day)	Total Annual Volume (Million Gals. Per Year)
Small	107	9520	2.5
Medium	101	58800	14.7
Large	33	73100	18.3
TOTALS	241	141420	35.4

The proper trickling volumes for each tank must be engineered from wastewater analyses and using the basic formulae. The proper flow will change greatly from shop to shop and from tank to tank within a single electroplating shop.

This technique has been demonstrated in three shops to date. In one example, a batch test system was installed in an electroplating room having an average process flow of 33,000 GPD (8 hrs.). Most major electroplating processes including various cleaning steps, nickel plating, copper plating and precious metal plating were in use during the time of the test. Even without the added advantage of trickling the dragout tanks, a daily dragout volume of approximately 400 gallons (as predicted by the earlier equations) was measured and was sufficient to allow the following improvement in total wastewater quality.

	Before Test (mg/l)	Using the Providence Method (mg/l)	Proposed Federal Regulation
Work rate (racks/hr.)	62	100	--
Total Cyanide	13.2*	1.8	1.9
Copper	11.5*	2.5	4.5
Lead	1.4*	0.44	0.6
Nickel	60.9*	4.4*	4.1
Silver	B.D.	B.D.	1.2
Zinc	0.28	0.41	4.2

* -In Excess of Federal Regulation
B.D. -Below Detection

The fact that the nickel standard was not quite met during this test points out the importance of a generous safety factor when establishing the trickling flow rate from each tank.

A major benefit of this technique is the added encouragement to recover the dragout solutions for their metal or acid values. In addition to the possibility of in-shop reuse after purification, our recovery investigation has identified a practical, economical recovery technology which could be used at a central plant. This technology is described in Section VIII: CENTRAL TREATMENT AND RECOVERY.

The reductions in capital and operating costs using this technique associated with recovery are significant. The least cost schemes using the Providence method were determined after a series of calculations and are presented in Table 8 for the "typical" small, medium and large shops.

TABLE 8

COST BREAKDOWN
LEAST-COST SIMPLE DRAGOUT CAPTURE SCHEMES
WITH AND WITHOUT 10,000 GPD EXEMPTION

	Small (5850 GPD)	Medium (35,850 GPD)	Large $183,800 GPD)
Scheme: With 10,000 GPD exemption	Haul to Central	Reduce below 10,000 GPD & batch treat in-shop	Haul to Central
Capital Cost			
Simple dragout setup	$ 6,050	$ 25,410	$ 50,820
pH neutralization	--	19,360	60,000
Batch treatment	--	18,880	--
Storage	14,520	--	29,040
TOTAL CAPITAL COST	$20,570	$63,650	$139,860
If 10,000 GPD exemption is dropped	$20,570	$61,460 (Haul to Central)	$139,860
Operating Cost			
Amortization	$ 3,640	$11,266	$ 24,755
Water/sewer charges	1,830	3,100	40,000
Analytical	2,400	2,400	4,800
Labor & batch operation	--	12,337	16,925
Sludge disposal	--	--	--
Haul & central processing	1,980	--	49,860
TOTAL ANNUAL COST	$9,850	$29,103	$136,340
If 10,000 GPD exemption is dropped	$9,740	$38,465 (Haul to Central)	$133,570

VIII. CENTRAL TREATMENT AND RECOVERY

The only practical central facility concept for the study area is one in which some form of flow reduction is performed in the individual shops and the resulting concentrated waste is hauled to the central facility by tank truck. The technology at central that would result in the lowest TOTAL ANNUAL cost to the shops include metal and acid recovery using electrolytic techniques. Cyanide destruction and metals precipitation with solids separation would be required to complete the treatment process to meet environmental standards. Figure 2 depicts the proposed quantified process flow scheme. The electrolytic step accomplishes recovery of metals and regeneration of acids from spent acids solutions and acid dragouts concentrates, as well as metal recovery and cyanide destruction from cyanide type spent solutions and dragout concentrates. This recovery is only possible when wastes are sufficiently concentrated and segregated.

Tables 9 and 10 present itemized costs of construction and operation for a 41 million gal/yr. (164,000 gpd) central recovery facility (CRF). The unit processing cost of 6 1/2¢/gal is more than 2¢/gal less expensive than the unit processing cost for a central facility without recovery. Although the CRF is higher in capital cost due to the electrolytic equipment needed for recovery, the large savings derived from a (1) 95% reduction in sludge volumes requiring disposal, (2) reduced treatment chemicals and (3) the value of the recovered materials, far exceed the additional amortization due to this increased capital. This 2¢/gal. benefit makes central recovery clearly least cost as compared to central neutralization.

Figure 2
CENTRAL RECOVERY PROCESSING FACILITY
QUANTIFIED PROCESS FLOW SCHEME

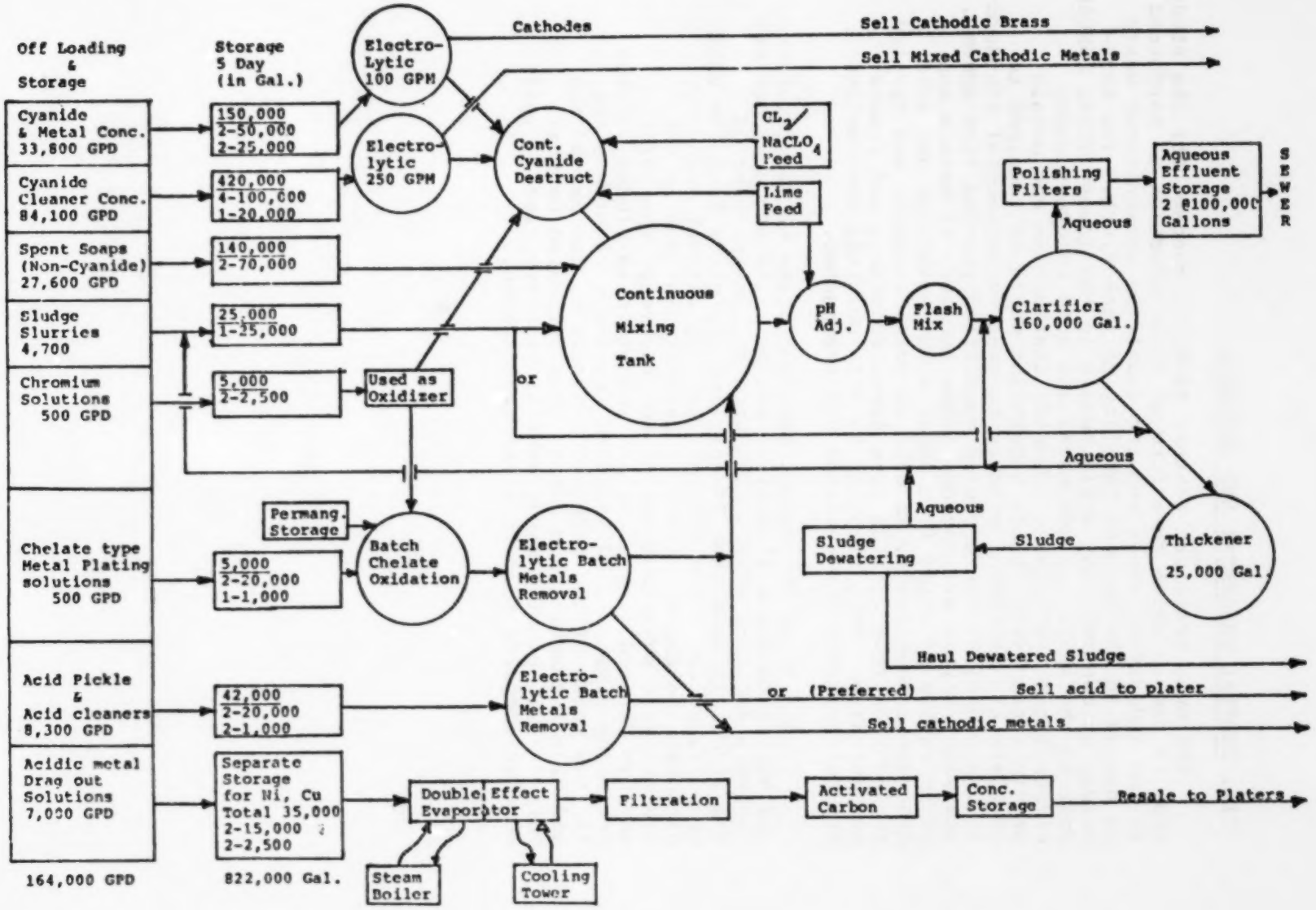


TABLE 9

200 GALLONS PER MINUTE

CENTRAL RECOVERY FACILITY (CRF)

CONSTRUCTION COST ESTIMATE

		1980 Dollars
A.	Site Work and Appurtenances	
1.	Site Preparation (3 acres)	$ 16,000
2.	Paving (100.000 sq. ft.)	103,000
3.	Excavation	26,000
4.	Utilities	
	- storm water collection, holding basin and pumping	74,000
	- sanitary sewer	22,000
	- water service	10,000
	- electrical power feeder	15,000
5.	Miscellaneous	
	- emergency spill tanks	10,000
	- weigh scale, 50 ton	20,000
	- fencing (2,000 L.F.)	28,000
	- yard and external building lighting	72,000
	- closed circuit T.V. (security)	8,000
	- guard house	8,000
	- scale house	8,000
	SUBTOTAL A	420,000
B.	Structures and Appurtenances	
1.	Processing Building (9,200 sq. ft.)	500,000
2.	Administration/Laboratory/Maintenance Building	350,000
3.	Secure Waste Transfer Area Roofing (21,000 sq. ft.)	250,000
4.	In Ground Concrete Waste Receiving Tanks	2,000,000
	SUBTOTAL B	3,100,000

SEE NEXT PAGE FOR CONTINUATION:

TABLE 9 (Continued)

200 GALLONS PER MINUTE

CENTRAL RECOVERY FACILITY (CRF)

CONSTRUCTION COST ESTIMATE

		1980 Dollars
C.	Process Equipment	
1.	Vessels	$ 80,000
2.	Agitators	39,000
3.	Pumps	200,000
4.	Clarifier/Flocculator (Tank and Mechanism)	90,000
5.	Thickener/Storage Tank (Tank and Mechanism)	10,000
6.	Chemical Systems	100,000
7.	Dewatering and Sludge Handling	100,000
8.	Aqueous Waste Polishing Filters	110,000
9.	Nickel Recovery	250,000
10.	Miscellaneous Facility Utilities Equipment	92,000
11.	Process Instrumentation and Control Equipment	100,000
12.	Vehicles	45,000
13.	Electrolytic Equipment	775,000
	SUBTOTAL C	1,991,000
D.	Equipment Installation (20% of Subtotal C.)	398,200
E.	Piping, Valves and Fittings (Process) (20% of Subtotal C. and D.)	477,840
F.	Electrical (15% of Subtotal C.)	298,650
G.	Subtotal (A. through F.)[1]	6,685,690
H.	Design Engineering (12% of Subtotal G.)	802,283
I.	Construction Management (4% of Subtotal G.)	267,428
J.	Contingency (10% of Subtotal G., H. and I.)	775,540
	TOTAL CONSTRUCTION COST	$8,530,940

(1) Includes contractor's overhead and profit

TABLE 10

SUMMARY OF CRF ANNUAL OPERATING COST(1)

	Item	Annual Cost (1980 Dollars)
1.	Annual Amortized Capital	$1,229,000
2.	Equipment Replacement Sinking Fund	54,000
3.	Manpower Costs	925,000
4.	Operating Cost Elements	
	A. Consumables	30,000
	B. Security (Contract Service)	88,000
	C. Technical Services	30,000
	D. Regulatory Compliance (included in C.)	--
	E. Equipment Maintenance and Repair	550,000
	F. Taxes, Insurance, Closure Fund	345,000
	G. Treatment Chemicals	10,000
	H. Utilities	90,000
	I. Ultimate Sludge Disposal	30,000
5.	Subtotal	3,381,000
6.	Credit: value(2) of reclaimed nickel,copper,acids	665,000
7.	Total Annual Operating Cost	$2,716,000
8.	Cost per gallon	6 1/2¢

(1) Operating 5 days per week, two - 8 hour shifts per day with an annual throughput of 41 million gal/yr.

(2) One half (1/2) of market value.

The unit charge (cents/gallon) of processing wastes at the facility is most sensitive to variations in waste volume processed. The unit charge increases with a reduction in the volume of waste processed. Too great an increase in the unit charge would make it less costly to treat in-shop than to recover at a central facility. The volume of waste received at the central facility depends on the degree of waste concentration obtained in-shop and the number and size of shops using the facility. It would require participation by nearly all 253 jewelry electroplaters to keep a unit charge of 6 1/2¢ per gallon using a central facility after a 99% reduction of pollutant bearing discharge streams by means of the "Providence method" or certain advanced methods. This type of participation will require a high degree of cooperation within the jewelry industry. However, the 42 large shops, which benefit most from a central facility with the federal 10,000 gpd exemption in effect, would contribute 60 percent of the 41 million gallons per day processed at central. An initial determination of project viability can thus be ascertained by polling these few shops to establish the degree of their participation. Also, the CRF would accept waste from the additional 123 non-jewelry metal finishers in the Rhode Island and Southeastern Massachusetts area. It could also provide treatment of other aqueous wastes such as oil-water or oil-solvent mixtures.

Of paramount importance is that the opportunity for recovery of acids and metals from segregated waste concentrates from small and medium size shops and some large shops will be lost if central recovery is not implemented before these shops install in-shop treatment equipment. We believe in-shop dragout concentration and direct recycle back to the plating bath will be adopted very cautiously by the industry due to the intense concern for a high quality finish in most jewelry goods. It will be predominantly the larger shops which will have the necessary technical expertise to reuse concentrated dragout wastes without adversely affecting the quality of goods produced.

Metal wastes which are not recovered will require treatment resulting in a sludge residue requiring long term storage or land disposal. Although a remaining secure landfill life of 25 years is claimed at the nearest facility in New York the costs of disposal are increasing rapidly each year. The siting of a regional secure landfill appears some years off making sludge disposal a very difficult problem when recovery is not maximized. Maximizing recovery is a major benefit of a central facility.

IX.

SUMMARY OF FINANCING OPTIONS AVAILABLE TO ELECTROPLATERS ON AN INDIVIDUAL BASIS

Evaluation Criteria / Financing Option	Financing Costs	Cash Equity and Collateral Requirements	Administrative Procedures and Costs	Eligibility Requirements
Conventional Loans	Interest rate will vary by the state of the economy and applicants financial status. Going rate is approximately 14 1/2%.	Varies by case. Loans generally available up to a maximum of 80% of project cost.	Document preparation and Processing is usually minimal. Audited financial statements and cash flow projections are usually required. Applicant should be prepared to pay "points" based on collateral.	Applicant must have a good credit history and exhibit the ability and plans to continue profitability.
Industrial Development Bonds/PCRB	Tax exempt status provides provides for below market interest rate of approximately 10 1/2%	No front-end cash requirements. Must exhibit a plan for debt service	Preparation of financial proposal. Bonds are issued by state or local government. Prepayment fees represent approximately 4% of total bond.	Must have high credit rating and proven ability to repay the bond.
SBA PCRB Guarantee	Tax exempt status and guarantee provides for below market interest rate of approximately 9 1/2%	No front-end cost requirements. Must exhibit a plan for debt service.	Preparation of financial proposal. Bonds are issued by state or local government. Prepayment fees represent approximately 4% of total bond. In addition, must complete and file appropriate forms with SBA.	Profitable small businesses which have been in business for 5 years and profitable for 3 years.
SBA Loan Guarantee	Expected interest rate is approximately 14%. Maximum guarantee is $500,000.	Applicants cash participation can be as little as 10%.	Must prepare financial documentation for commercial lender first. Administrative costs represent approximately 4% of total guarantee. Must supply detailed Pro Forma projections.	Must be a small business. Must exhibit the ability to repay debt service.
SBA Direct Loan	Expected interest rate is approximately 8 1/4%. Maximum direct loan is $500,000.	Must be negotiated with SBA on an individual basis.	Applicant must have exhausted all other financing alternatives. Must supply detailed Pro Forma projections.	Must be a small business. Applicant must first have tried to obtain a SBA guarantee loan.
SBIC	About the same as a conventional loan. But there is a $500,000 maximum.	Applicant may have to sell a part of the company equity to the SBIC in exchange for capital.	More involved than for a conventional loan.	Must be a small business.
EDA Loan Guarantees	Expected interest rate is approximately 14%.	Applicants cash participation can be as little as 10%.	Schedule a pre-application conference with EDA regional office, application is then made directly to EDA. Applicant must show the project assists in addressing local problems and has public support.	Area must be EDA designated. Eligible projects must promote opportunities for economic development, benefit long term unemployment,etc.
EDA Direct Loan	Expected interest rate is approximately 8 1/4%.	Direct loans up to 65% of project costs.	Schedule a pre-application conference with EDA regional office, application is then made directly to EDA. Applicant must show the project assists in addressing local problems and has public support.	Area must be EDA designated. Eligible projects must promote opportunities for economic development, benefit long term unemployment,etc.

X. CONCLUSIONS AND RECOMMENDATIONS

Metal finishing wastes from the study area emanate primarily from two sources -- high volume rinsewaters and low volume spent (dumped) solutions. The quest for least-cost solutions for the industry requires as its major focus an analysis of alternative pollutant concentration techniques to be performed prior to ultimate pollutant reuse or disposal. Since the USEPA has classified waste treatment sludge as "hazardous" even the conventional treatment approach is essentially a concentrating technique although cyanides are indeed destroyed by this method. However, this method does not "detoxify" the waste according to USEPA's classification.

Five concentrating alternatives were examined for application to a "typical" small (5850 GPD), medium (35,850 GPD) and large (183,800 GPD), jewelry electroplating shop. These flows are based on 8 hour work days. The five alternatives examined were conventional treatment at 100% flow (no concentration), conventional treatment at 50% flow, conventional treatment at 10% flow, advanced methods obtaining 1 to 2.5% flow requiring treatment, and the simple dragout capture technique developed under this project and requiring treatment of 1% of the flow. For each alternative an optimum (least-cost) scheme was developed and costed for two cases - one assuming all processing is performed in-shop, the other assuming the wastes are concentrated in-shop but further processed at a central facility. In addition, schemes were developed and costed for the present situation where the 10,000 gpd federal exemption for metals is in effect and for the future situation if the exemption is removed. Initial capital and total annual costs were developed for each scheme. Total annual costs are the best basis for comparison as they include both amortized capital costs and annual operating costs. We have defined "least-cost" solutions as those having the lowest total annual cost. The simple dragout capture technique demonstrated in 3 local jewelry shops to date clearly results in the least-cost and in most cases least-space alternative for all shop sizes both with and without the federal exemption in effect. This is primarily because it is the least-cost means of concentrating rinsewater pollutants prior to reuse or disposal. Whenever feasible, the concentrate should be returned to the bath with proper care. This approach is particularly suitable for nickel, which comprises 42% of all metal pollutants discharged. When direct return of concentrate is not possible it can be either (1) batch treated in-shop and the resulting sludge hauled away to Connecticut or upperstate New York for disposal, or (2) stored in compartmented tanks totaling 2500 to

5000 gallons in size and hauled to a proposed central recovery facility.

It can be seen from Table 11 that significant cost savings are obtained with simple dragout capture over the more traditional conventional treatment alternative with 50% flow reduction. Capital cost savings of $43,150, $159,730 and $281,760; and total annual cost savings of $17,110/yr., $60,080/yr. and $44,090/yr. are obtained for the "typical" small, medium and large jewelry metal finisher, respectively. Based upon a jewelry industry comprised of the 253 plants in the Providence study area, total initial capital savings are $30,000,000 and annual cost savings are over $9,000,000 per year.

TABLE 11

COST COMPARISONS BETWEEN CONVENTIONAL TREATMENT
AND USE OF THE PROVIDENCE METHOD
WITH EXISTING REGULATIONS IN EFFECT

	Small (5,850 GPD)	Medium (35,850 GPD)	Large (183,800 GPD)
Capital Cost[1] using the Providence Method	$20,570	$63,650	$139,860
Total Annual Cost[1] using the Providence Method	9,850	29,103	136,340
Capital Cost[2] with 50% Flow Reduction	63,750	223,380	421,600
Total Annual Cost[3] with 50% Flow Reduction	26,960	89,180	180,430

(1) See Table 8 for more information
(2) See Table 4 for more information
(3) See Table 5 for more information

The other four alternatives ranked according to increasing total annual cost are as follows:

1. Conventional treatment with 90% flow reduction (Countercurrent rinses or sprays on all polluting streams)
2. Advanced methods, particularly reverse osmosis and ion exchange whenever technically feasible. Recovery by these methods is only economically justified for the large shop
3. Conventional with 50% flow reduction
4. Conventional with no flow reduction

Regarding the central facility option, with the federal exemption in effect it is economically beneficial for the small and large shop to haul concentrates to a central recovery facility at a cost of 9¢ per gallon (haul plus process charge). The large shop saves over $90,000, or about 40%, in initial capital cost. Due to the exemption however, it is less costly for the medium shops, having flows ranging from 16,000 GPD to about 40,000 GPD, to use the simple dragout capture technique, reduce flows to under 10,000 GPD, and treat in-shop. This is because the concentrates require treatment only for cyanides and this volume of concentrates from the simple dragout capture technique increases proportionately as total water flow is reduced. Thus, if a 40,000 GPD shop reduces rinse flow by 75% to 10,000 GPD the dragout requiring treatment increases from about 400 GPD to 1600 GPD. For these shops it is less expensive to reduce flow and treat in-shop than to reduce flow and haul and recover at a central plant.

However, if the 10,000 GPD federal exemption is removed all shops would incur significant total annual savings with the availability of a central recovery facility. Total annual cost savings with central processing of 40%, 14% and 4%; and capital savings of 23%, 37% and 39% would be obtained by the small, medium and large shops, respectively. Total annual jewelry industry savings with central would be over $1,500,000.

Table 12 presents a brief description and costs for a "typical" small, medium and large shop for the various options under the least-cost alternative.

The central recovery scheme requires participation by nearly all jewelry electroplaters in the study area in order to maintain processing charges at 7 cents per gallon. Participation should be readily assessed since 42 (17%) of the shops would contribute 60% of the waste. This unit charge of 7¢ per gallon is based upon an $8,500,000 facility

sized for 200 gpm and handling 164,000 gpd operating 2-8 hour shifts. Significant additional waste would be available from the 123 non-jewelry metal finishers identified in the study area and companies requiring sludge dewatering. Although not included in the present scheme other aqueous wastes such as oil-water and oil-solvent mixtures could be processed. This diversity would provide a facility baseload to partially offset the usual "ups and downs" of jewelry industry production.

The proposed central facility would receive about 30 to 50 trucks per day and provide 3 to 5 days up front and 1 to 2 days back-end storage of waste water. Necessary mechanical redundancies including emergency power generation would be provided. Use of the simple dragout technique optimizes recovery of materials by not only concentrating but also segregating waste streams. Thus, central recovery will not only reduce the sludge volume requiring disposal by over 95 percent, but will also return 290,000 gallons of plating bath strength nickel, 150,000 pounds of copper as brass, and 2,000,000 gallons of acid, all conservatively valued at $665,000 annually, to industry.

Very importantly, the central facility would not only reclaim metals and acids but would reduce sludge volumes requiring disposal by over 95%. Reliance on out of state secure landfills would be greatly reduced. A non-measurable benefit of a central facility is that the jewelry shops can continue their concentration on manufacturing and production and need not get into the waste treatment business. Also, with a central facility all shops in the industry would incur waste disposal costs at about the same time. This may be important in competitive pricing of finished products. Since financial viability of the central facility depends upon its use by the large shops, a commitment to construct such a facility is imperative prior to the large shops investing in the in-shop treatment option. For these reasons, immediate implementation of simple dragout capture in-shop followed by storage and haul of concentrates to central recovery facility is recommended.

TABLE 12
COMPARATIVE COST OF SCHEMES
USING THE SIMPLE DRAGOUT CAPTURE TECHNIQUE

			Capital Cost	Total Annual Cost
1. Small Shop With Exemption				
A.	IN-SHOP PROCESSING	.Dragout tanks on cyanide and strong acid streams .Batch cyanide chlorination .Batch acid neutalization	20,600	10,930
B.	CENTRAL PLANT PROCESSING	.Dragout tanks on cyanide and strong acid streams .On-site storage,haul and electrolytic cyanide destruction and metals and acid recovery at central	20,600	9,850
2. Small Shop Without Exemption				
A.	IN-SHOP PROCESSING	.Dragout tanks on cyanide, acid and metal streams .Batch cyanide chlorination, metals precipitation and acid neutralization .Sludge store and haul @ $0.30/gallon	26,620	16,120
B.	CENTRAL PLANT PROCESSING	.Dragout tanks on cyanide, acid and metal streams .On-site storage,haul and electrolytic cyanide destruction and metals and acid recovery at central	20,600	9,740
3. Medium Shop With Exemption				
A.	IN-SHOP PROCESSING	.To less than 10,000 GPD via dragout tanks on all streams .Batch cyanide chlorination .Continuous pH adjustment	63,650	29,100
B.	CENTRAL PLANT PROCESSING	.Dragout tanks on all streams but not to achieve less than 10,000 GPD .On-site storage and haul cyanide and metal streams to central recovery .Continuous on-site pH adjustment	61,450	39,190

TABLE 12 (Continued)

			Capital Cost	Total Annual Cost
4.	Medium Shop Without Exemption			
A.	IN-SHOP PROCESSING	.Dragout tanks on all streams .Batch cyanide chlorination and metals precipitation/ pH adjustment .Sludge settle,dewater and dispose @ $190/ton in drum lots	98,250	44,890
B.	CENTRAL PLANT PROCESSING	.Dragout tanks on all streams but not to achieve less than 10,000 GPD .On-site storage and haul cyanide and metal streams to central recovery .Continuous on-site pH adjustment	61,450	38,460
5.	Large Shop With Exemption			
A.	IN-SHOP PROCESSING	.Dragout tanks on all polluting streams .Batch cyanide chlorination .Batch metal precipitation and settling .Sludge dewater and dispose @ $135/ton in bulk lots .Continous pH adjustment	230,490	138,750
B.	CENTRAL PLANT	.Dragout tanks on all polluting streams .Cyanide and metals store and haul to central recovery .Continous pH adjustment	139,860	136,340
6.	Large Shop Without Exemption			
A.	IN-SHOP PROCESSING	.Dragout tanks on all polluting streams .Batch cyanide chlorination .Batch metal precipitation and settling .Sludge dewater and dispose @ $135/ton in bulk lots .Continuous pH adjustment	230,490	138,750
B.	CENTRAL PLANT PROCESSING	.Dragout tanks on all polluting streams .Cyanide and metals store and haul to central reovery .Continuous pH adjustment	139,860	133,570

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